Naval Fuels & Lubricants
Cross Functional Team
Research Report

EVALUATION OF THE IMPACT OF A SYNTHETIC PARAFFINIC KEROSENE AND JP-8 BLEND ON FILTERS AND FILTER/COALESCER PERFORMANCE

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EXECUTIVE SUMMARY

Synthetic Paraffinic Kerosene (SPK) is a liquid hydrocarbon fuel which can be produced by several different methods, one of which being the Fischer Tropsch (FT) process. First invented during the 1920's, the FT process involves a chemical reaction which converts a hydrogen and carbon monoxide mixture into a liquid hydrocarbon fuel, typically from sources like coal or natural gas. Since 70 percent of the petroleum currently used in the U.S. is imported, certification of SPK is being pursued because of the benefits to energy security over traditional petroleum derived fuel. SPK can be made from domestic feed stocks which will reduce the U.S. dependence on foreign energy. The goal is to certify up to 50 percent synthetic aviation fuel in petroleum aviation fuel for use in military applications.

This program evaluated the effects of a 50/50 blend of SPK and petroleum aviation fuel with and without the standard JP-8 additive package on filter/coalescer performance. The filter/coalescer elements tested were representative of those currently used in military and commercial filtration systems. The program included performance and compatibility testing. Results of the testing were:

- A neat 50/50 blend of SPK and petroleum aviation fuel did not adversely affect performance of API 1581 5th edition Category C or M100 style elements or MIL-PRF-32148 elements.

- A 50/50 blend of SPK and petroleum aviation fuel (with and without the standard JP-8 additive package) performed identically to the 100% petroleum fuel when tested with API 1581 3rd edition style elements. Both the SPK/petroleum blend and the straight petroleum based fuel failed performance testing due to exceeding the differential pressure requirement during the solids injection.

- A 50/50 blend of SPK and petroleum aviation fuel with the JP-8+100 additive package failed API 1581 5th edition Category M100 performance testing due to exceeding the differential pressure requirement during the solids injection. Test results indicate the 50/50 blend was not the cause for failure because the identical test with the neat 50/50 blend passed the API requirements.

- Compatibility testing of a 50/50 blend of SPK and petroleum aviation fuel containing the standard JP-8 additive package and API 1581 3rd edition and 5th edition Category C, M, and M100 elements showed no impact to fuel properties or element integrity.

- Compatibility testing of a neat 50/50 blend of SPK and petroleum aviation fuel and API 1581 5th edition Category M100 and 3rd edition elements showed no impact on fuel properties or element integrity.

- Compatibility testing of a neat 50/50 blend of SPK and petroleum aviation fuel and API 1581 5th edition Category M and C elements adversely impacted fuel thermal stability, however there was no impact to element integrity.

LIST OF ACRONYMS/ABBREVIATIONS

DoD.. Department of Defense

FSII ....Fuel System Icing Inhibitor

FT..Fischer Tropsch

GC/MS .... Gas Chromatography/Mass Spectroscopy

ICP .... Inductively Coupled Plasma

JFTOT...Jet Fuel Thermal Oxidation Tester

SET .... Single Element Test

SPK ....Synthetic Paraffinic Kerosene

WSIM..Water Separation Index, Modified

Evaluation of the Impact of a Synthetic Paraffinic Kerosene and JP-8 Blend on Filters and Filter/Coalescer Performance

1.0 BACKGROUND

Synthetic Paraffinic Kerosene (SPK) is a liquid hydrocarbon fuel which can be produced by several different methods, one of which being the Fischer Tropsch (FT) process. First invented during the 1920's, the FT process involves a chemical reaction which converts a hydrogen and carbon monoxide mixture into a liquid hydrocarbon fuel, typically from sources like coal or natural gas. The goal is to certify up to 50 percent synthetic aviation fuel in petroleum aviation fuel for use in military applications. Since 70 percent of the petroleum currently used in the U.S. is imported, certification of SPK is being pursued because of the benefits to energy security over traditional petroleum derived fuel. SPK can be made from domestic feed stocks which will reduce the U.S. dependence on foreign energy.

2.0 OBJECTIVE

This program evaluated the effects of a 50/50 blend of SPK and petroleum aviation fuel on military and commercial filter/coalescer performance in two phases. The first phase evaluated the effects on filter/coalescer performance of the SPK/petroleum blend with and without the required additives included in the JP-8 specification (MIL-DTL-83133). The second phase of the program evaluated the material compatibility between the SPK blend and the filter/coalescers and separators with and without the required additive package.

3.0 APPROACH

3.1 Impact on Filter/Coalescer Performance

The first part of the test plan consisted of twelve single element tests (SET). The tests utilized filter elements that were manufactured in accordance with API 1581 3rd edition, 5th edition, and MIL-PRF-32148 for Navy shipboard filter elements. A list of the details of each test is shown in Table 1.

3.2 Impact on Material Compatibility

The second part of the test plan consisted of testing the material compatibility between the SPK/petroleum blend fuel and the filter/coalescers and separators used in the first part of the test plan. The plan consisted of a modified version of API 1581 Section 4.6.2. A list of the details of the testing is shown in Table 2. The Category M separator, which is the Navy style element, was the only separator tested for this compatibility testing because the materials used presented the worst case scenario.

Table 1: Single Element Testing Details

Test No.	Fuel	Element Type	Filter Element	Separator Type	Test Edition	Flow Rate (gpm)	Additives	Primary User
1A	Pet.	3rd Ed. Style	I-42087	Basket Type	API 1581 3rd Ed	20	Stadis 450, Hitec 580	Army
1B	Pet.	3rd Ed. Style	I-42087	Basket Type	API 1581 3rd Ed	20	Stadis 450, Hitec 580	Army
2A	SPK /Pet.	3rd Ed. Style	I-42087	Basket Type	API 1581 3rd Ed	20	N/A	Army
2B	SPK /Pet.	3rd Ed. Style	I-42087	Basket Type	API 1581 3rd Ed	20	N/A	Army
3	SPK /Pet.	3rd Ed. Style	I-42087	Basket Type	API 1581 3rd Ed	20	Stadis 450, Hitec 580	Army
4A	SPK /Pet.	3rd Ed. Style	I-42087	Basket Type	API 1581 3rd Ed	20	Stadis 450, DCI-4A, DiEGME	Army
4B	SPK /Pet.	3rd Ed. Style	I-42087	Basket Type	API 1581 3rd Ed	20	Stadis 450, DCI-4A, DiEGME	Army
5	SPK /Pet.	Category M	I-420MMF	SS424Z	MIL-PRF-32148	35	N/A	Navy
6	SPK /Pet.	Category M100	I-420A4	Basket Type	API 1581 5th Ed	20	N/A	Air Force
7	SPK /Pet.	Category C	TC-CO131	TC-S0113	API 1581 5th Ed	45.5	N/A	Industry
8A	SPK /Pet.	Category M100	I-420A4	Basket Type	API 1581 5th Ed	20	Stadis 450, DCI-4A, DiEGME, Spec-Aid 8Q462	Air Force
8B	SPK /Pet.	Category M100	I-420A4	Basket Type	API 1581 5th Ed	20	Stadis 450, DCI-4A, DiEGME, Spec-Aid 8Q462	Air Force

Table 2: Material Compatibility Testing Details

Test No.	Element	Product No.	Element Type	Additives
1-1	F/C	I-42087	3rd Ed. Style	N/A
1-2	F/C	I-420MMF	5th Ed. Category M	N/A
1-3	F/C	I-420A4	5th Ed. Category M100	N/A
1-4	Sep.	SS424Z	5th Ed. Category M	N/A
1-5	F/C	TC-CO131	5th Ed. Category C	N/A
2-1	F/C	I-42087	3rd Ed. Style	Stadis 450, DCI-4A, DiEGME
2-2	F/C	I-420MMF	5th Ed. Category M	Stadis 450, DCI-4A, DiEGME
2-3	F/C	I-420A4	5th Ed. Category M100	Stadis 450, DCI-4A, DiEGME, Spec-Aid 8Q462
2-4	Sep.	SS424Z	5th Ed. Category M	Stadis 450, DCI-4A, DiEGME
2-5	F/C	TC-CO131	5th Ed. Category C	Stadis 450, DCI-4A

3.3 Fuels and Additives
Two test fuels were used for the program. The fuel used for Test 1A and 1B was a straight petroleum derived aviation fuel. Fuel used for Tests 2A – 8B was a 50 percent mixture of SPK (produced using natural gas through the FT process) and the petroleum aviation fuel used in Tests 1A and 1B. Table 3 contains the specification properties of each fuel. The additives that were used for testing are shown in Table 4.

Table 3: Fuel Specification Test Results

Characteristic	ASTM Test Method	Petroleum Results (Fuel 1)	SPK Results	SPK/Pet. Results (Fuel 2)	Units
API Grav 15ºC		42.4	57.8	50.2	
Appearance		Clear & Bright	Clear & Bright	Clear & Bright	
Aromatics, FIA	D 1319	21.2	0.0*	10.5	vol. %
Color, Saybolt	D 156	+22	+30	+26	
Cu Strip Corrosion	D 130	1a	1a	1a	
Density @ 15ºC	D 4052	0.813	0.747	0.779	g/mL
Distillation					
Initial Boiling Point		162	154	156	deg C
10% Point		180	161	163	deg C
50% Point		210	172	186	deg C
90% Point		251	197	237	deg C
End Point		279	246	271	deg C
Residue		1.4	1.5	1.5	vol. %
Loss	D 86	0.2	0.0	0.0	vol. %
Doctor Test	D 4952	Negative	Negative	Negative	
Electrical Conductivity	D 2624	16	75	46	pS/m
Existent Gum	D 381	0.5	1.6	0.5	mg/100 mL
Filtration Time	Spec Test	5.05	3.79	4.86	min./gal
Flash Point	D 93	52	45	47	deg C
Freezing Point	5972	-46	-57	-55	deg C
FSII Content	D 5006	0.15	0.06	0.03	vol. %
Heating Value	D 4809	43.0	44.2	43.6	MJ/kg
Hydrogen Content	D 7171	13.6	15.2	14.5	mass %
MSEP (Water Separation Rating)	D 3948	91	97	92	
Olefins, FIA	D1319	1.6	0.5	1.4	vol. %
Particulate Matter	D 5452	0.5	0.6	0.2	mg/L
Saturates, FIA	D1319	77.2	96.4	88.1	vol. %
Smoke Point	D 1322	25	34	31	mm
Sulfur Content	D 4294	0.07	0.01	0.04	mass %
Total Acid Number	D 3242	0.003	0.002	0.002	mg KOH/g
Viscosity @ -20ºC	D 445	5.0	2.7	3.5	cSt

* Subject to limitations of the test method.

Table 4: Fuel Additives

Additive Function	Additive Name	Concentration
Static Dissipater Additive	Stadis 450	2.0 mg/L (1.0, cat. C)
Fuel System Icing Inhibitor	DiEGME	0.15%vol
Corrosion Inhibitor	DCI-4A	15 mg/L
Corrosion Inhibitor	Hitec 580	15 mg/L
Thermal Stability Additive (+100)	Spec-Aid 8Q462	256 mg/L

3.4 Protocols and Limits

3.4.1 Single Element Testing The protocols of API 1581 3rd edition, 5th edition, and MIL-PRF-32148 and the pass/fail limits have been included in Tables 5 and 6 respectively. The data for each single element test can be found in Appendix A Table A-1.

3.4.2 Material Compatibility Testing The modified protocol derived from API 1581 Section 4.6.2 for the material compatibility consisted of soaking each element for a total of one month in a volume of fuel 5 times the outer dimensions of the element in stainless steel housings. The fuel was tested for select properties (listed in Table 7) initially and then after a two week period. The housings were then drained of fuel and fresh fuel was added to the same elements for another two week period and the resulting fuel samples were tested again. In addition, each element was visually inspected each time the housings were drained of fuel. This protocol was then repeated with the additive packages described in Table 2. The pass/fail requirements are shown in Table 7. The data for each material compatibility test can be found in Appendix B Tables B-1 through B-5.

Table 5: Single Element Test Protocol

Test Phase	Duration API 1581 3rd Ed.	Duration API 1581 5th Ed./ MIL-PRF-32148
Conditioning/Media Migration	45 min	30 min
Water Injection (100 ppm)	Not Included	30 min
Solids Injection (133 / 72 mg/gal)	75 min (RIO I-116)	75 min (90% U.F./10% R9998)
Water Injection (100 ppm)	60 min	150 min
Water Injection (3%)	30 min	30 min

Table 6: API 1581/MIL-PRF-32148 Pass/Fail Limits

Contaminant	Maximum Allowable API 1581	Maximum Allowable MIL-PRF-32148
Fibers	10 per liter	10 per liter
Solids Content*	0.26 mg/L	0.26 mg/L
Free Water	15 ppm	10 ppm

* Differential pressure during the solids injection may not exceed 15 psi in 50 min or 45 psi in 75 min.

Table 7: Material Compatibility Pass/Fail Requirements

Test	Requirement for Failure
WSIM	< 85 (Test 1)
Water Reaction Interface	> 1b (Test 1 & 2) and/or
Water Reaction Separation	> 2
Saybolt Color	Decrease by > 4 units (Test 1 & 2)
Thermal Stability	> 3 or abnormal in nature
Existent Gum	Increase by 8mg/100mL*

* If existent gum increases by more than 3mg/100mL after the first soak period, the increase during the second soak period shall be less than 50% of the increase measured during the first soak.

4.0 DISCUSSION

4.1 Single Element Testing

The single element tests were run using three different types of housings with rated flow rates representative of DoD systems currently in place. Before each test, the test fuel was water washed, clay treated, and prepared with the specified additives as described in Table 1. Including retests, there were a total of twelve single element tests performed. All test data is contained in Appendix A Table A-1.

4.1.1 Test 1 API 1581 3rd edition single element testing was performed using a vertical canister filter separator test housing rated at 20 gpm that is representative of the type used in tactical systems (shown in Figure 1). This housing is designed for one 4” x 20” coalescer element with a slipover separator. The fuel used was the 100% petroleum aviation fuel. After the 45 min element conditioning phase and the solids injection, the low water injection was initiated, but was terminated after 10 min due to passing greater than 15 ppm of free water which fails the requirement for effluent free water as listed in Table 6. The test was not continued further due to the effluent free water failure. The effluent solids content downstream of the element up to this point was unaffected and the differential pressure (dP) across the element was low at 3 psi.

The results of the first tests indicated that the separator may not have been set correctly, so a retest was performed using water washed, clay treated, and newly additized fuel. The same test procedures were followed, verifying that the element and separator were installed correctly, only this time the dP across the element rose to 15 psi in 35 min during the solids injection, which fails the requirement listed in Table 6. Solids injection continued until the pressure reached 75 psi, which is the rated pressure the element can withstand, 55 minutes into the phase.

Figure 1: 20 gpm Vertical Canister Filter Separator

4.1.2 <u>Test 2</u> API 1581 3rd edition single element testing was conducted using the 20 gpm vertical canister test housing shown in Figure 1 and the SPK/petroleum blend. After the element conditioning phase, the solids injection with RIO I-116 was started. After approximately 10 min, the differential pressure across the element reached the pass/fail limit of 15 psi before the specified 50 min. The test was allowed to continue past this point in order to collect more data. After the 75 min solids injection, the element dP was measured at 60 psi. The test continued with the low water injection which resulted in passing free water readings of <15 ppm. The test was finally terminated 10 min into the high water injection because the dP reached 75 psi, which is the rated pressure the element can withstand. It is also noted that at this point the free water reading was above 15 ppm. The effluent solids content downstream of the element throughout the test was below the pass/fail limit shown in Table 6.

The test was rerun using the 90/10 mixture of A1 UltraFine ISO 12103-1 and Copperas Red Iron Oxide R9998 test dust instead of the Red Iron Oxide I-116. Because the dP increased so rapidly using the RIO I-116, the effects on filtration using the 90/10 mix (API 1581 5th Ed. standard) was evaluated as a comparison with the initial results of the test. The procedure for the retest remained the same except for this change and the test passed all the requirements.

4.1.3 <u>Test 3</u> API 1581 3rd edition single element testing was performed using the 20 gpm vertical canister test housing shown in Figure 1 and the SPK/petroleum blend. At approximately 5 min into the solids injection with RIO I-116, the dP reached the 75 psi threshold that the filter can withstand and the solids injection was stopped. The housing was taken offline from the main system because of the rapid rise in pressure. When the housing was put back online with the system, the dP had dropped to 27 psi. Since flow through the test element was stopped, the solids trapped in the filter could have settled or redistributed while the housing was offline, which would explain the decrease in pressure when flow was reintroduced to the element. The decision was made to not continue the solids injection since the pressure had increased so rapidly. Instead, the test was resumed at the low water injection and continued to the high water phase. Only the last free water reading during the high water injection was above the effluent water level of >15 ppm at which point the differential pressure was 56 psi. Effluent solids content throughout the test remained below the pass/fail limit.

4.1.4 Test 4 API 1581 3rd edition single element testing was performed using the 20 gpm vertical canister test housing shown in Figure 1 and the SPK/petroleum blend. After the element conditioning phase, the solids injection with RIO I-116 began, but was terminated after 25 min when the dP across the element reached 15 psi. The test continued with the low and high water injection. The high water phase ended after 10 min when the effluent water level remained above the pass/fail limit of >15 ppm. The dP at this point was recorded at 40.5 psi. Effluent solids content throughout the test was below the pass/fail limit listed in Table 6.

The test was rerun using the 90/10 mixture of A1 UltraFine ISO 12103-1 and Copperas Red Iron Oxide R9998 instead of the Red Iron Oxide I-116 for the reasons stated previously. The retest again provided a failure at 25 min into the solids injection due to dP. The test was continued until the dP reached 75 psi which occurred 10 min into the low water injection. At the point when the test was stopped, the free water reading was 12 ppm (just below the pass/fail limit of 15 ppm).

After further research and discussions with the filter/coalescer manufacturer, a couple possible explanations have been hypothesized for why the testing with API 1581 3rd edition elements (Table 1 Tests 1-4) failed the requirements due to pressure increase. First, industry research has shown that additives play a role in dirt dispersion in kerosene jet fuel. Additive-free fuel allows some particle agglomeration to take place whereas the common fuel additives that were used in this testing have the tendency to break up these particles into much smaller ones. These finer particles will penetrate the filter media further and cause an increased flow restriction, therefore causing the differential pressure to rise much more rapidly.

Another possible reason for increased differential pressure is the method that the test dust is injected into the system. The 3rd edition procedure allowed for the red iron oxide to be added into the system dry which would produce more particle agglomeration before it reached the test element. The procedure used for this program follows the 5th edition protocol which calls for mixing the test dust into the fuel in a large tank and then injecting the slurry into the system. The slurry was mixed using a recirculation pump as well as an impeller for no less than 30 min before being injected. This type of mixing could sufficiently break up any agglomerations of particles before reaching the test element, much more so than simply adding the red iron oxide in dry.

While there are a couple possible reasons why the differential pressure increased so rapidly during testing, there is no evidence to suggest that it was the use of the 50/50 blend of SPK and petroleum fuel that led to these failures. Tests 1B and 3 were run under the same conditions with the same additives, the only difference being the type of fuel, and the same type of failure was produced. Thus the conclusion can be made that because these tests resulted in a similar outcome, the SPK/petroleum blend performed the same as the straight petroleum fuel.

4.1.5 Test 5 MIL-PRF-32148 single element testing was conducted using a Velcon VV1033150NVY filter separator test housing which is the official test housing for Navy 4” shipboard elements. This housing (shown in Figure 2) is built to API standards with a side by side element configuration and designed for a 35 gpm flowrate. It is designed for two 4” x 20” elements and one 4” x 24” separator. The fuel used for this test was the SPK/petroleum blend without additives and the test dust used was the 90/10 mixture of A1 UltraFine ISO 12103-1 and Copperas Red Iron Oxide R9998 for the solids injection phase. This test was run according to MIL-PRF-32148 and passed all the requirements listed in Table 6.

Figure 2: 35 gpm Vertical Side by Side Filter Separator

4.1.6 Test 6 API 1581 5th edition single element testing was performed with a Category M100 filter/coalescer and used the 20 gpm vertical canister test housing shown in Figure 1. The fuel used for this test was the SPK/petroleum blend without additives and the test dust used was the 90/10 mixture of A1 UltraFine ISO 12103-1 and Copperas Red Iron Oxide R9998 for the solids injection phase. This test passed all the API 1581 5th edition requirements listed in Table 6. During the high water injection, one of the free water readings was 12 ppm, which is close to the limit of 15 ppm required by API 1581, but still passes the requirement. The effluent fuel was retested throughout the remainder of the test and the readings continued to measure below the threshold.

4.1.7 Test 7 API 1581 5th edition single element testing was conducted with a Category C filter/coalescer and used an Aircraft Appliances and Equipment Ltd, 710994 filter separator test housing, built to API standards and designed for a 45.5 gpm flowrate (shown in Figure 3). This housing is configured for one 6” x 20” coalescer and one 6” x 7” separator side by side and is the official test housing for Navy 6 inch shipboard elements. This test passed all the API 1581 5th edition requirements listed in Table 6. The fuel used for this test was the SPK/petroleum blend without additives and the test dust used was the 90/10 mixture of A1 UltraFine ISO 12103-1 and Copperas Red Iron Oxide R9998 for the solids injection phase.

Figure 3: 45.5 gpm Vertical Side by Side Filter Separator

4.1.8 Test 8 API 1581 5th edition single element testing was conducted using the Army test housing shown in Figure 1 and the SPK/petroleum fuel. The Category M100 filter/coalescer was tested using fully additized fuel as described in Table 1, which included Spec-Aid8Q462. During the solids injection, the test narrowly missed passing the differential pressure requirement of 15 psi in 50 min. The dP crept up to 15 psi at approximately 40 min into this phase. The test was allowed to continue and maintained solids and water removal during the low water injection, but during the high water injection the effluent free water measured above the pass/fail limit of 15 ppm described in Table 6.

Since the results were on the threshold of passing, Test 8 was rerun. The test was rerun using water washed, clay treated, and newly additized fuel and the results produced were almost identical to the first run. The dP rose to 15 psi in 45 min and subsequently allowed greater than 15 ppm of free water to pass during the high water injection.

Further research and discussions with the filter/coalescer manufacturer did not produce any concrete reasons as to why there was a gradual rise in pressure during the solids injection. The only difference between Test 8 and Test 6 was the use of approved JP-8+100 additives. Test 6 passed the API test requirments and Test 8 did not, so the conclusion can be made that the SPK/petroleum blend was not the cause for failure because the fuel was used in both tests. Also, because the results were just below the differential pressure requirements of API 1581 5th edition, it should be noted that if the required amount of solids during a test were being injected into a fielded system, the pressure increase would have triggered a change out of the elements before off-spec fuel would have been passed downstream of the filter separator.

4.2 Material Compatibility Testing

Each material compatibility test was performed using the 50% blend of SPK and petroleum fuel. Before testing, the fuel was water washed, clay treated, and tested to ensure that the fuel was clean, dry, and additive free. Each stainless steel housing (shown in Figures 4 and 5) was soaked in the test fuel for approximately 24 hours and then rinsed with fuel before the test began. The fuel used for the material compatibility testing was stored in sealed, epoxy-lined 55 gallon drums. This ensured that each round of testing began with the same baseline fuel.

Figure 4: 4 inch element housings

Figure 5: 6 inch element housing

Once the testing with neat fuel was complete, the baseline fuel was doped with the appropriate additives required for each type of filter as described in Table 2. During this second set of testing, it should be noted that the first set of samples taken at the two week point were inadvertently discarded before the test was complete. Due to time constraints, the test was not restarted, but continued as the test plan described for the full month, with new test fuel being added to the elements. The results from the material compatibility tests are shown in Appendix B Table B-1 through Table B-5.

During the course of Test 1 (neat test fuel) and Test 2 (additized test fuel), there were no apparent visual differences in appearance or color between the elements being tested and new elements except for a slight discoloration of the outer cloth material of the filter/coalescers on the area that was actually touching the metal of the container. This occurred because the tubes were sitting at a slight angle as seen in Figure 4. A summary of both tests are in Sections 4.2.1 and 4.2.2.

4.2.1 Test 1 (neat test fuel) Results of the JFTOT testing for Test 1 showed 4 out of 10 samples failed the differential pressure requirement. The samples that did not pass the requirement of a dP < 25 mmHg were the Category C filter/coalescer and Category M separator at 2 weeks, and the Category C and M filter/coalescers at one month. These results were verified by the Air Force Petroleum Lab (shown in Appendix C). These pressure increases were most likely not due to particulates in the fuel since the fuel is filtered many times when performing a JFTOT test, the smallest pore size of these filters being 0.45 micron. What could possibly have happened is that compounds leached from the elements into the fuel and a chemical reaction in the hot section of the tester was causing these compounds to polymerize into higher molecular weight compounds which could travel downstream and clog the small, mesh dP filter where the pressure across the tube is measured. ICP trace metals analysis (shown in Appendix D) did not reveal abnormal levels that could cause these thermal stability failures, but GC/MS testing by the AFPET Lab on one of the Category C samples did reveal the presence of a plasticizer (di-n-octyl-phthalate). All other analyses required in Test 1 passed the requirements listed in Table 7.

4.2.2 Test 2 (test fuel with additives) Test 2 provided all passing results, however the Saybolt color rating for the fuel containing the Category M separator dropped by more than the pass/fail limit of 4 units described in Table 7. The fuel was slightly darker than the rest of the samples taken at the time which may possibly indicate a contamination of some kind; however, color is not always a reliable guide in which to measure contamination. This decrease in color only occurred during Test 2, not Test 1, so the requirement was met satisfactorily. Also, the water reaction interface rating for the sample of fuel taken at 4 weeks containing the M100 filter/coalescer was rated at 2, which is greater than the pass/fail limit of a 1b rating. This result was verified by a retest of a 2nd sample of fuel, but since it only occurred once during both sets of testing then the requirement was met satisfactorily. All other analyses required in Test 2 passed the requirements listed in Table 7.

It is important to note that the WSIM results for this test are below the minimum limit specified in Table 7. This was expected since the additives used are commonly known to reduce the WSIM value to below the minimum value specified. Another point to note is that none of the fuel samples taken during Test 2 failed JFTOT testing, as did 4 samples during Test 1.

5.0 CONCLUSIONS

5.1 Single Element Testing

- A neat 50/50 blend of SPK and petroleum aviation fuel did not adversely affect performance of API 1581 5th edition Category C or M100 style elements or MIL-PRF-32148 elements.

- A 50/50 blend of SPK and petroleum aviation fuel (with and without the standard JP-8 additive package) performed identically to the 100% petroleum fuel when tested with

API 1581 3rd edition style elements. Both the SPK/petroleum blend and the straight petroleum based fuel failed performance testing due to exceeding the differential pressure requirement during the solids injection.

- A 50/50 blend of SPK and petroleum aviation fuel with the JP-8+100 additive package failed API 1581 5th edition Category M100 performance testing due to exceeding the differential pressure requirement during the solids injection. Test results indicate the 50/50 blend was not the cause for failure because the identical test with the neat 50/50 blend passed the API requirements.

5.2 Material Compatibility Testing

- Compatibility testing of a 50/50 blend of SPK and petroleum aviation fuel containing the standard JP-8 additive package and API 1581 3rd edition and 5th edition Category C, M, and M100 elements showed no impact to fuel properties or element integrity.

- Compatibility testing of a neat 50/50 blend of SPK and petroleum aviation fuel and API 1581 5th edition Category M100 and 3rd edition elements showed no impact on fuel properties or element integrity.

- Compatibility testing of a neat 50/50 blend of SPK and petroleum aviation fuel and API 1581 5th edition Category M and C elements adversely impacted fuel thermal stability, however there was no impact to element integrity.

6.0 RECOMMENDATIONS

- Further single element testing on API 1581 3rd Ed style elements with fuel containing military additives should not be considered. These elements were never approved for use with these additives and future testing is expected to yield similar failing results.

- Further material compatibility testing with a 50/50 blend of SPK and petroleum aviation fuel with API 1581 Category M and C filter/coalescers and separators should be considered. This would include a retest of the element soak and corresponding fuel property analysis.

- The particle dispersion effects of a 50/50 blend of SPK and petroleum aviation fuel as well as straight petroleum aviation fuel should be evaluated. Particle size distribution of the test dust in each type of fuel should be investigated to determine if there is a difference due to fuel composition and/or use of approved additives.

7.0 REFERENCES

1. API 1581 Third Edition, Specifications and Qualification Procedures for Aviation Jet Fuel Filter/Separators. American Petroleum Institute: Washington, DC. May 1989.

2. API/IP 1581 Fifth Edition, Specifications and Qualification Procedures for Aviation Jet Fuel Filter/Separators. American Petroleum Institute and The Institute of Petroleum: London. July 2002.

3. MIL-DTL-83133, Detail Specification, Turbine Fuels, Aviation, Kerosene Types, NATO F-34 (JP-8), NATO F-35, and JP-8+100, dated 1 April 1999.

4. MIL-PRF-32148, Performance Specification, Filter Separator Elements, Fluid, Pressure, Aviation and Distillate Fuel, Naval Shipboard, dated 25 July 2005.

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Appendix A – Filter Coalescer Performance Test Results

Table A-1: Single Element Test Data

Test #	Element Type	Solids Type	Fuel	Additives	Fibers (#)	Max Low Water (ppm)	Max Effluent Solids (mg/L)	Max Low Water (ppm)	Max High Water (ppm)	Test Failure Section	Time to Fail (min into section)
1A	I-42087	RIO I-116	Pet.	Stadis 450, Hitec 580	2	-	0.12	>15	-	2nd Low Water	10
1B	I-42087	RIO I-116	Pet.	Stadis 450, Hitec 580	0	-	0.19	-	-	Solids Inj. Pressure	35
2A	I-42087	RIO I-116	SPK /Pet.	N/A	1	-	0.14	2	>15	Solids Inj. Pressure	10
2B	I-42087	U.F./R9998	SPK /Pet.	N/A	0	-	0.14	1	4.5	-	-
3	I-42087	RIO I-116	SPK /Pet.	Stadis 450, Hitec 580	1	-	0.07	2	>15	Solids Inj. Pressure	5
4A	I-42087	RIO I-116	SPK /Pet.	Stadis 450, DCI-4A, DiEGME	1	-	0.08	2.5	>15	Solids Inj. Pressure	25
4B	I-42087	U.F./R9998	SPK /Pet.	Stadis 450, DCI-4A, DiEGME	0	-	0.15	12	-	Solids Inj. Pressure	25
5	I-420MMF	U.F./R9998	SPK /Pet.	N/A	4	1	0.03	1.5	1.5	-	-
6	I-420A4	U.F./R9998	SPK /Pet.	N/A	1	1	0.14	1.5	12	-	-
7	TC-CO131	U.F./R9998	SPK /Pet.	N/A	0	1.5	0.09	1.5	2	-	-
8A	I-420A4	U.F./R9998	SPK /Pet.	Stadis 450, DCI-4A, DiEGME, Spec-Aid 8Q462	3	3	0.19	5	>15	Solids Inj. Pressure	40
8B	I-420A4	U.F./R9998	SPK /Pet.	Stadis 450, DCI-4A, DiEGME, Spec-Aid 8Q462	2	2	0.2	2	>15	Solids Inj. Pressure	45

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Appendix B: Material Compatibility Test Results

Table B-1: 3rd Ed. Style Filter/Coalescer Compatibility Results (Elem. I-42087)

Test	Time (hr)	MSEP	Water Reaction		Saybolt Color	Thermal Stability		Existent Gum (mg/100mL)	Visual Inspection
			Int.	Sep.		Tube Rating	dP (mmHg)		
1. (blend w/o addit.)									
Initial	0	100	1	1	25	1	0.0	0.0	
	336	98	1	1	26	<1	0.0	0.4	Localized discoloration
	Diff.	-2	0	0	+1	n/a	0.0	+0.4	due to contact w/ housing
Second	0	100	1	1	25	1	0.0	0.0	
	336	97	1	1	26	1	0.0	0.8	Localized discoloration
	Diff.	-3	0	0	+1	n/a	0.0	+0.8	due to contact w/ housing
2. (blend w/ addit.)									
Initial	0	65	1	1	25	<1	0.1	2.8	
	336	-	-	-	-	-	-	-	Localized discoloration
	Diff.	--	--	--	--	--	--	--	due to contact w/ housing
Second	0	65	1	1	25	<1	0.1	2.8	
	336	58	1	1	26	<1	0.0	1.4	Localized discoloration
	Diff.	-7	0	0	+1	n/a	-0.1	-1.4	due to contact w/ housing

Table B-2: Category M Filter/Coalescer Compatibility Results (Elem. I-420MMF)

Test	Time (hr)	MSEP	Water Reaction		Saybolt Color	Thermal Stability		Existent Gum (mg/100mL)	Visual Inspection
			Int.	Sep.		Tube Rating	dP (mmHg)		
1. (blend w/o addit.)									
Initial	0	100	1	1	25	1	0.0	0.0	
	336	99	1	1	25	<1	0.0	2.4	Localized discoloration
	Diff.	-1	0	0	0	n/a	0.0	+2.4	due to contact w/ housing
Second	0	100	1	1	25	1	0.0	0.0	
	336	89	1	1	26	1	280.0	0.2	Localized discoloration
	Diff.	-11	0	0	+1	n/a	+280.0	+0.2	due to contact w/ housing
2. (blend w/ addit.)									
Initial	0	65	1	1	25	<1	0.0	2.8	
	336	-	-	-	-	-	-	-	Localized discoloration
	Diff.	--	--	--	--	--	--	--	due to contact w/ housing
Second	0	65	1	1	25	<1	0.0	2.8	
	336	57	1	1	26	<1	0.1	1.8	Localized discoloration
	Diff.	-8	0	0	+1	n/a	+0.1	-1.0	due to contact w/ housing

Table B-3: Category M100 Filter/Coalescer Compatibility Results (Elem. I-420A4)

Test	Time (hr)	MSEP	Water Reaction		Saybolt Color	Thermal Stability		Existent Gum (mg/100mL)	Visual Inspection
			Int.	Sep.		Tube Rating	dP (mmHg)		
1. (blend w/o addit.)									
Initial	0	100	1	1	25	1	0.0	0.0	
	336	97	1	1	26	1	0.3	2.0	Localized discoloration
	Diff.	-3	0	0	+1	n/a	+0.3	+2.0	due to contact w/ housing
Second	0	100	1	1	25	1	0.0	0.0	
	336	100	1	1	26	1	0.0	0.2	Localized discoloration
	Diff.	0	0	0	+1	n/a	0.0	+0.2	due to contact w/ housing
2. (blend w/ addit.)									
Initial	0	42	1b	1	27	<1	0.0	3.4	
	336	46	1b	2	26	<1	0.0	4.0	Localized discoloration
	Diff.	+4	0	+1	-1	n/a	0.0	+0.6	due to contact w/ housing
Second	0	42	1b	1	27	<1	0.0	3.4	
	336	49	2	2	26	1	0.0	5.6	Localized discoloration
	Diff.	+7	+1	+1	-1	n/a	0.0	+2.2	due to contact w/ housing

Table B-4: Category M Separator Compatibility Results (Elem. SS424Z)

Test	Time (hr)	MSEP	Water Reaction		Saybolt Color	Thermal Stability		Existent Gum (mg/100mL)	Visual Inspection
			Int.	Sep.		Tube Rating	dP (mmHg)		
1. (blend w/o addit.)									
Initial	0	100	1	1	25	1	0.0	0.0	
	336	100	1	1	25	1	280.0	0.8	OK
	Diff.	0	0	0	0	n/a	+280.0	+0.8	
Second	0	100	1	1	25	1	0.0	0.0	
	336	100	1	1	24	<1	11.8	0.0	OK
	Diff.	0	0	0	-1	n/a	+11.8	0.0	
2. (blend w/ addit.)									
Initial	0	65	1	1	25	<1	0.0	2.8	
	336	-	-	-	-	-	-	-	OK
	Diff.	--	--	--	--	--	--	--	
Second	0	65	1	1	25	<1	0.0	2.8	
	336	58	1	1	18	<1	2.2	1.8	OK
	Diff.	-7	0	0	-7	0	+2.2	-1.0	

Table B-5: Category C Filter/Coalescer Compatibility Results (Elem. TC-CO131)

Test	Time (hr)	MSEP	Water Reaction		Saybolt Color	Thermal Stability		Existent Gum (mg/100mL)	Visual Inspection
			Int.	Sep.		Tube Rating	dP (mmHg)		
1. (blend w/o addit.)									
Initial	0	100	1	1	25	1	0.0	0.0	
	336	91	1	1	26	1	280.0	4.8	OK
	Diff.	-9	0	0	+1	n/a	+280.0	+4.8	
Second	0	100	1	1	25	1	0.0	0.0	
	336	88	1	1	25	1	153.0	0.4	OK
	Diff.	-12	0	0	0	n/a	+153.0	+0.4	
2. (blend w/ addit.)									
Initial	0	45	1	1	25	<1	0.1	1.4	
	336	-	-	-	-	-	-	-	OK
	Diff.	--	--	--	--	--	--	--	
Second	0	45	1	1	25	<1	0.1	1.4	
	336	*	1	1	26	<1	0.0	1.2	OK
	Diff.	--	0	0	+1	n/a	-0.1	-0.2	

* Not enough sample to perform analysis

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Appendix C: JFTOT Results from AFPET Laboratory

AFPET LABORATORY REPORT
HQ AFPET/PTPLA
2430 C Street
Building 70, Area B
Wright-Patterson AFB, OH 45433-7632

Lab Report No: 2009LA17230001	Protocol: IA-AVI-0001	Cust Sample No: NONE GIVEN
Date Sampled: 03/25/2009	Date Received: 03/27/2009	Date Reported: 04/21/2009

Sample Submitter:
HQ AFPET/PTOT
2430 C Street
Building 70, Area B
Wright-Patterson AFB, OH 45433-7632

Reason for Submission: Investigative Analysis
Product: Aviation Turbine Fuel, Kerosene
Specification: Special Request Grade:JP-8

Source: pax river initial SPK Qty Submitted: 1 L

Method	Test	Min	Max	Result
ASTM D 3241 - 08a	Thermal Stability @ 260°C			
	Tube Deposit Rating, Visual			1
	Change in Pressure (mmHg)			0
GC/MS	Gas Chromatography (Mass Spectroscopy)	Report Only		See Below

Dispositions:
For information purposes only.
This sample appears to be a typical jet fuel sample. The GC/MS scan shows no high-molecular weight volatile compounds present, either before or after the thermal stability test.

Approved By	**Date**
Miguel Acevedo, Chief \\SIGNED\\	04/21/2009

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afpet.afth@wpafb.af.mil, anthony.viscomi@wpafb.af.mil, cheryl.mccormick@wpafb.af.mil, david.craycroft@wpafb.af.mil, miguel.acevedo@wpafb.af.mil, timothy.mudry@wpafb.af.mil

AFPET LABORATORY REPORT
HQ AFPET/PTPLA
2430 C Street
Building 70, Area B
Wright-Patterson AFB, OH 45433-7632

Lab Report No: 2009LA17230002	Protocol: IA-AVI-0001	Cust Sample No: 09087-00805-000
Date Sampled: 03/25/2009	Date Received: 03/27/2009	Date Reported: 04/21/2009

Sample Submitter:
HQ AFPET/PTOT
2430 C Street
Building 70, Area B
Wright-Patterson AFB, OH 45433-7632

Reason for Submission: Investigative Analysis
Product: Aviation Turbine Fuel, Kerosene
Specification: Special Request Grade:JP-8

Source: pax river category m Qty Submitted: 1 L

Method	Test	Min	Max	Result
ASTM D 3241 - 08a	Thermal Stability @ 260°C			
	Tube Deposit Rating, Visual			1
	Change in Pressure (mmHg)			219
GC/MS	Gas Chromatography (Mass Spectroscopy)	Report Only		See Below

Dispositions:
For information purposes only.
This material appears to be a typical jet fuel. The GC/MS scan showed no high-boiling volatile coumpounds present, both before and after the JFTOT test.

Approved By	Date
Miguel Acevedo, Chief \\SIGNED\\	04/21/2009

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AFPET LABORATORY REPORT
HQ AFPET/PTPLA
2430 C Street
Building 70, Area B
Wright-Patterson AFB, OH 45433-7632

Lab Report No: 2009LA17230004	Protocol: IA-AVI-0001	Cust Sample No: 09071-00749-000
Date Sampled: 03/25/2009	Date Received: 03/27/2009	Date Reported: 04/21/2009

Sample Submitter:
HQ AFPET/PTOT
2430 C Street
Building 70, Area B
Wright-Patterson AFB, OH 45433-7632

Reason for Submission: Investigative Analysis
Product: Aviation Turbine Fuel, Kerosene
Specification: Special Request Grade:JP-8

Source: pax river category c f/c Qty Submitted: 1 L

Method	Test	Min	Max	Result
ASTM D 3241 - 08a	Thermal Stability @ 260°C			
	Tube Deposit Rating, Visual			1
	Change in Pressure (mmHg)			280
GC/MS	Gas Chromatography (Mass Spectroscopy)	Report Only		See Below

Dispositions:
For information purposes only.
This material appears to be a typical jet fuel with one minor exception. The GC/MS scan revealed the presence (0.004%) of a plasticizer (di-n-octyl-phthalate) both before and after JFTOT testing.

Approved By	Date
Miguel Acevedo, Chief \\SIGNED\\	04/21/2009

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AFPET LABORATORY REPORT
HQ AFPET/PTPLA
2430 C Street
Building 70, Area B
Wright-Patterson AFB, OH 45433-7632

Lab Report No: 2009LA17230003	Protocol: IA-AVI-0001	Cust Sample No: 09087-00808-000
Date Sampled: 03/25/2009	Date Received: 03/27/2009	Date Reported: 04/21/2009

Sample Submitter:
HQ AFPET/PTOT
2430 C Street
Building 70, Area B
Wright-Patterson AFB, OH 45433-7632

Reason for Submission: Investigative Analysis
Product: Aviation Turbine Fuel, Kerosene
Specification: Special Request Grade:JP-8

Source: pax river category c f/c Qty Submitted: 1 L

Method	Test	Min	Max	Result
ASTM D 3241 - 08a	Thermal Stability @ 260°C			
	Tube Deposit Rating, Visual			1
	Change in Pressure (mmHg)			280
GC/MS	Gas Chromatography (Mass Spectroscopy)	Report Only		See Below

Dispositions:
For information purposes only.
This material appears to be a typical jet fuel. The GC/MS scan showed that no volatile high-boiling point compounds were present, both before and after JFTOT testing.

Approved By	Date
Miguel Acevedo, Chief \\SIGNED\\	04/21/2009

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Appendix D: Results from Inductively Coupled Plasma Analysis

Table D-1: Results from ICP Metals Analysis on Material Compatibility Samples

Test	Initial SPK blend w/o addit.	Cat. M F/C 1 month sample w/o addit.	Cat. M Sep. 2 week sample w/o addit.	Cat. C F/C 2 week sample w/o addit.	Cat. C F/C 1 month sample w/o addit.	Units
Aluminum	0.022	<0.021	<0.021	<0.021	<0.021	ppm
Barium	<0.002	<0.002	<0.002	<0.002	<0.002	ppm
Boron	0.065	0.023	<0.023	<0.023	0.027	ppm
Cadmium	0.017	<0.009	<0.009	<0.009	<0.009	ppm
Calcium	0.013	0.006	0.016	0.012	0.015	ppm
Chromium	<0.007	<0.007	<0.007	<0.007	<0.007	ppm
Copper	0.002	<0.002	0.022	<0.002	<0.002	ppm
Iron	<0.004	<0.004	0.004	<0.004	<0.004	ppm
Lead	<0.033	<0.033	<0.033	<0.033	<0.033	ppm
Lithium	0.035	0.026	0.027	0.025	0.028	ppm
Magnesium	0.002	0.001	0.003	0.001	0.001	ppm
Manganese	0.001	<0.001	<0.001	<0.001	<0.001	ppm
Molybdenum	<0.029	<0.029	<0.029	<0.029	<0.029	ppm
Nickel	<0.020	<0.020	<0.020	<0.020	<0.020	ppm
Phosphorus	<0.027	<0.027	<0.027	<0.027	<0.027	ppm
Potassium	<0.048	<0.048	<0.048	<0.048	<0.048	ppm
Silicon	0.133	0.237	0.104	12.1	1.83	ppm
Silver	0.015	0.004	0.005	<0.004	0.006	ppm
Sodium	0.654	0.400	0.485	0.394	0.451	ppm
Tin	<0.074	<0.074	<0.074	<0.074	<0.074	ppm
Titanium	<0.002	<0.002	<0.002	<0.002	<0.002	ppm
Vanadium	0.003	<0.002	<0.002	<0.002	<0.002	ppm
Zinc	0.008	<0.005	0.005	0.015	<0.005	ppm

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14. ABSTRACT
Synthetic Paraffinic Kerosene (SPK) is a liquid hydrocarbon fuel which can be produced by several different methods, one of which being the Fischer Tropsch (FT) process. Since 70 percent of the petroleum currently used in the U.S. is imported and SPK can be produced from domestic hydrocarbon sources such as coal and natural gas, certification of SPK for use as a blending component in JP-8 fuel is being pursued to enhance US energy security. This program evaluated the effects of a 50/50 blend of SPK and petroleum aviation fuel with and without the standard JP-8 additive package on filter/coalescer performance. The filter/coalescer elements tested were representative of those currently used in military and commercial filtration systems. The presence of the SPK blending component in the fuel did not impact the performance of the filter/coalescer elements.

15. SUBJECT TERMS
SPK, Synthetic Paraffinic Kerosene, FT Fuel, Fischer-Tropsch Aviation Fuel, Alternate Aviation Fuel, Coalescer Performance

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
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